Evaluation of Ablators for Use in the Ares I Upper Stage Thermal Protection System

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Abstract

Ablators are integral to the performance of thermal protection systems (TPS) intended for spaceflight vehicles. To evaluate how well a particular ablator will perform, bond tension tests must be conducted on samples to determine the ultimate tensile adhesion strength of the materials in different environments such as liquid nitrogen, liquid hydrogen, room temperature, or elevated temperatures. The ultimate tensile adhesion strength relates to several other properties of the ablator that will determine whether it is a potential candidate for use in the TPS. For this project, different ablators were evaluated for incorporation into the Ares I Upper Stage (US) TPS. Ablator bond tension tests of different materials were conducted in liquid nitrogen, gaseous nitrogen, room temperature air, and elevated temperatures of air. The ultimate tensile adhesion strengths of the ablators were then calculated using the data obtained.

Background

- Ablators are materials that can quickly dissipate heat from a heat source by melting and carrying hot gas away with them. This process is termed “blowing.”
- Proposed ablator applications for the Ares I US are in typical high heat areas, such as the plume impingement areas or fairings.
- The following ablator candidates were evaluated for inclusion in the Ares I US TPS:
  - Thermal Management Coating (TMC), SP1 and SP2 formulations
  - Marshall Convergent Coating-1 (MCC-1)
  - P50 Cork
- Test samples consisted of a block-mounted ablator that was then bonded to a mounted aluminum 2219 substrate using a primer (see Figure 1 below).

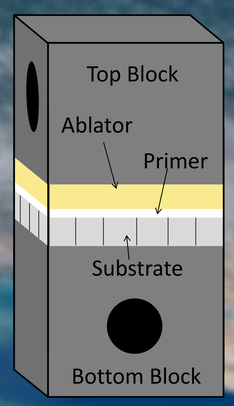

Figure 1: Diagram of an ablator test sample

Figure 2: Liquid nitrogen test frame

Test Setup

- Ablator bond tension tests were conducted in a wide range of temperatures to simulate actual conditions aboard a spacecraft. Three specimens of each ablator were tested in each of the following four environments:
  - Liquid nitrogen (-320 °F, see Figure 2 above)
  - Gaseous nitrogen (-200 °F)
  - Room temperature air (75 °F)
  - Elevated temperature air (250 °F)
- Actual temperatures and actual dimensions of the samples were recorded prior to testing.
- Samples were then mounted in test frames. See Figure 2 above for a standard liquid nitrogen test frame and Figure 3 below for a room temperature test setup.
- Test specimens were pulled at a rate of 0.050 inches per minute, and data was collected at an acquisition rate of 5 Hertz (5 points per second).
- Samples were pulled until failure was reached and the blocks separated.

Figure 3: A test sample mounted for room temperature testing

Results

- Test samples failed by cohesive failure of the ablator, adhesive failure between the ablator and the primer, adhesive failure between the ablator and the substrate, or a combination of the above (Figure 4).
- The ultimate load the specimen was able to hold (Figure 5) was divided by the initial cross-sectional area to determine the bond adhesion tensile strength.
- All ablator candidates performed well above the minimum requirements of the test.
- MCC-1 performed notably better than the other candidates in the bond tension test. The TMC SP1 formulation was the next best performer, followed by the TMC SP2 formulation and lastly by the P50 cork.*

Figure 4: A broken MCC-1 test sample that exhibits all three kinds of failure

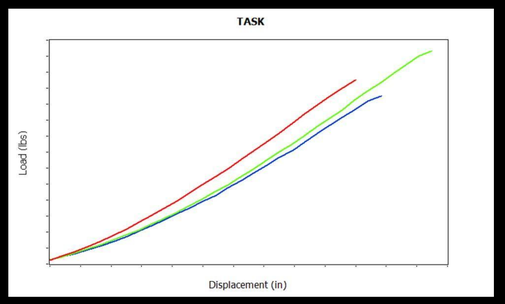

Figure 5: A typical load versus displacement curve for a specimen*

Conclusion

- MCC-1 is the best ablator candidate for the Ares I US when considering bond tension.
- Other factors may influence the final choice, such as thermal or chemical properties of the ablators.
- Further testing is needed in different areas to determine which ablator is best suited for the Ares I US.

References

Ares I Upper Stage Ablator Lead. “US-TPS-TP13 .“ Revision 2. March 24, 2009.

“Earth Orbit.” *Space Animation*. Media Fusion. Online. 13 July 2010. <http://www.spaceanimation.com/earthorbit.html>.

* Some data could not be shown due to SBU/ITAR restraints